

(London, Pittsburgh, New York City; Liège; U.S.S.R) (Greenburg et al.; Patno; Stocks; Ferstadt; Firket). It has as yet not been proposed that such fluctuations in lung cancer rates in different sections of an urban community are attributable to variations in the cigarette smoking habit of their inhabitants.

6. Size of Cities, Number of Inhabitants, Density of Population

Another manifestation of the irregular regional distribution of lung cancers is represented by the consistent gradient from high to low rates observed between population groups living in central portions of metropolitan areas and those residing in more peripheral portions. This phenomenon coincides with the process of progressive urbanization associated with a migration of population from overcrowded centers of large cities into areas with lower population densities in their peripheral portions (Brooke) which took place during last century. Such shifts of populations with their associated move away from polluted parts of communities provide also the basis for the observation of Stocks concerning the direct relation between lung cancer rates and the degree of population density, and they are also in harmony with the fact that the urban lung cancer rates rise with the number of inhabitants of metropolitan areas, since it is obvious that the size of the industrial parts of such communities and the density of automobile traffic in them should increase with the size of these urban centers and so would their occupational, general environmental and home degree and extent of air pollution. Such observations have been reported from

Austria, England, United States, Canada (Registrar General; Stocks; Manos; Prindle; Katz; Sellers);

Daly; Haenszel, Loveland and Sirken; Mancuso; Herbich and Neubold). It is significant that Prindle did not find any marked variations in the percentage of habitual cigarette smokers in populations of communities of different numbers of inhabitants ranging from over 1,000,000 to rural areas. Daly also noted that there was little indication that the average amount smoked varied very much from one group of towns to another. If the number of cigarette smoked

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Table 17

**Relation of Density of Population in Urban Areas to Lung Cancer Rates 1946-1949  
(P. Stocks)**

Groups of Conurbations with More Than 200,000 Inhabited Houses:	Mortality Rate
(London, East Ham, West Ham, Croydon.....	156
Birmingham, Smethwick, Walsall, West Bromwich.....	134
Liverpool, Bootle, Birkenhead, Wallasey.....	164
Manchester, Salford, Stockport.....	159
Leeds, Bradford, Halifax.....	132
Sheffield with 124,000 Inhabited Houses.....	135
Newcastle and Gateshead with 87,000 Inhabited Houses.....	114
Groups of Cities each with 50,000 to 85,000 Inhabited Houses.....	113
Groups of 3 Cities each with 40,000 to 50,000 Inhabited Houses.....	107
Groups of 12 Cities each with 30,000 to 40,000 Inhabited Houses.....	104
Groups of 13 Cities each with 20,000 to 30,000 Inhabited Houses.....	100
Groups of 29 Cities each with less than 20,000 Inhabited Houses.....	89

Table 18

**TABLE 17—STANDARDIZED MORTALITY RATIOS FOR LUNG  
CANCER, ENGLAND AND WALES, 1950-1954**

Population Group	Males	Females
Urban Areas	108	105
Conurbations	125	123
Urban Areas, 100,000 and over	111	100
Urban Areas, 50,000-100,000	93	90
Urban Areas, under 50,000	84	85
Rural Districts	66	77
England and Wales	100	100

Source: Registrar-General's Statistical Review, 1957.

Table 20

**TABLE 8.—Lung Cancer Mortality Rate for Metropolitan Areas of Different  
Numbers of Inhabitants**

**Metropolitan Areas Having Inhabitants From:**

1,000,000 to 9,500,000	500,000 to 1,000,000	100,000 to 500,000	50,000 to 100,000
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**Low Ratio:**

Boston	0.8	Worcester	0.5
Pittsburgh	0.9	New Haven	0.8

Pittsfield	0.3	Charlotte	0.3
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Green Bay	0.2
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Lima	0.3
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**High Ratio:**

Buffalo	2.1	Birmingham	2.9
Washington, D. C.	1.7	Kansas City	2.1

Mobile	2.8	Pueblo	1.7
Columbia	2.5	Amarillo	1.7

Los Angeles 1.6

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Table 15

Mortality Rates of Cancer of the Trachea, Bronchus and Lung  
for White Males and Percentage of Habitual Male Cigarette  
Smokers in Different Regions

R.A.Prindle.

Type of Region	Death Rate for 100,000 Inhabitants	Percentage of Habitual Cigar- ette Smokers
Cities with more than 1,000,000 inhabitants	29.4	48.5
Urban areas with 250,000 to 1,000,000 inhabitants	22.9	49.5
Urban areas with less than 250,000 inhabitants	17.5	47.8
Rural areas	14.6	42.5

Table 16

TABLE 16.—Standardized lung-cancer mortality ratios\*—adjusted for age, for persons with only 1 exposure residence and residing in current place of residence over 10 years—by population size, for selected diagnostic categories—U.S. white males, age 35 and over, 1958

Exposure residence †	Well-established diagnoses			
	All deaths	Total	Adenocarcinomas	Epidermoid and undifferentiated carcinomas
SMR				
Total	93	93	108	90
500,000 and over	133	126	118	119
50,000-500,000	119	127	102	138
10,000-50,000	102	122	252	99
2,500-10,000	94	94	100	79
Rural nonfarm	71	74	90	72
Farm	40	34	52	32
Observed deaths				
Total	956	735	151	504
500,000 and over	355	255	43	172
50,000-500,000	213	175	25	136
10,000-50,000	103	95	35	55
2,500-10,000	48	37	7	22
Rural nonfarm	145	115	25	80
Farm	92	58	16	39

\*SMR for each diagnostic category (adjusted for age by the indirect method) = 100 for U.S. white males, age 35 and over, 1958.  
†Size as of 1950.

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Table 21

## URBAN-RURAL STUDY OF NONSMOKERS\*

Pop. studied†	Lung ca. death rate/100,000 men‡
Cities >50,000	14.7
Cities 10,000-50,000	9.3
Suburban or town	4.7
Rural	0.

\*Hammond and Horn.<sup>10</sup>†White men 50 to 69 years of age in study population  
of 9 states of the United States, 1952-1955.‡The relative difference in lung cancer death rates  
between the large cities and suburban areas was 213%.

Table 22

Similar variations are noted in the Ontario data for 1954-58

TABLE 5—REGIONAL VARIATION IN LUNG CANCER MORTALITY, MALES  
ONTARIO, 1954-1958

Population Group	Actual	Expected	S.M.R.
Cities, 100,000 and over	1,394	962.8	145
Cities, 35,000-99,999	340	303.7	112
Rest of Ontario	1,782	2,249.5	79
TOTAL	3,516	3,516.0	100

Sellers

Table 23

Table 8: Lung cancer mortality rates, per 1,000  
deaths by sex, in Austria, 1954 (Herbig and  
Neubold)

Community	Total	Males	Females
Vienna	32.7	59.0	7.8
Cities 60,000-1,000,000	18.2	31.6	5.0
Cities 20,000-60,000	18.4	32.3	3.9
Remainder of Austria	10.3	17.3	3.7

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per males in the groups of towns evaluated, an increase of about 18 per cent in cigarette consumed was related to a 63 per cent increase in the lung cancer death rate, thereby furnishing evidence that a study of "density aggregates" reveals a clear trend from rural area to conurbation for lung cancer, which is absent, according to Dale, for all "non-respiratory diseases". When in a recent study Anderson et al. could not discover any relation between urban air pollution and lung cancer when comparing lung cancer rates for inhabitants of a rural town, Chilliwack, B.C. and an industrial town, Berlin, N.H., it seems that the presence of a considerable coal tar and pitch fume hazard for the workers employed in the large paper factory in Berlin escaped their attention, although the long term existence of a considerable number of skin cancers among such workers has been common knowledge for some time (Hueper).

In view of the claims made for the importance of cigarette smoking in the causation of lung cancer and impressed by the evidence connecting urbanization with this cancer, Myddelton recently demanded further research and a critical reappraisal of statistics heretofore reported. This request deserves attention in view of the data on tobacco smoking and size of community in Denmark and the United States recorded by Hamtoft and Lindhardt and by ~~Hannestad and~~ 1957 on of Lung Cancer.

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## 7. Rural-Urban Lung Cancer Rates

Numerous epidemiologic investigations have demonstrated the existence of a considerable gradient between lung cancer death rates seen in urban areas and rural districts (Finland; Smithies and England and Wales; U.S.A., Northern Ireland; Canada; Austria; Belgium; Norway; Japan; Germany) (Korpela and Magnus; Stocks; Curwen, Kennaway and Kannway; Campbell and Kreyberg; Howe; Lawther and Waller; Commins; Haenszel; Mills; Waller; Gorham; Wynder and Hammond; Saruta, Ishinishi, Kodama and Munitake; Herbich and Neubold; Poche, Mittmann and Kneller; Reding; Banyai; Lew; Stocks and Campbell; Best et al., Dean; Buell, Dunn and Breslow). According to Stocks and Campbell only a part of the differences between rural and urban lung cancer rates could be accounted for by differences in local cigarette smoking habits of males. Only 7 per cent of a difference of 45% in lung cancer rates in Cheshire and Lancashire county areas which were in excess to that observed in North Wales could be accounted for by local differences in smoking, only 8 per cent of a total of 79 per cent excess were attributable to this cause, and only about 30 per cent of an excess of 138 per cent were due to smoking in the lung cancer rates of Liverpool. From his statistical analyses Stocks concluded that in the absence of smoking and of urbanisation the sex ratio for lung cancer approaches unity. Gorham found that the lung cancer death rate in the most polluted districts of urban character was 25-30 per cent higher than in the least polluted urban areas and nearly double that of the rural death rate. Chemical analyses recorded by Stocks; Commins; and others have clearly shown that high pollution of urban air with carcinogenic aromatic hydrocarbons exists in comparison to that found in rural air. Table 24-28

Despite these epidemiologic and chemical findings Breslow, Lawther and Waller; Waller; Hammond and Wynder; and Clemmesen insist that air pollution plays either a minor role or no role at all in bringing about the differences in urban-rural lung cancer rates and that cigarette smoking is

Table 24

Cancer of Lung and Larynx, England and Wales  
(Kennaway and Kennaway)  
1946-1949.

Type of Community	Lung Cancer Ratio-Number of Persons Producing One Death		Larynx Cancer Ratio-Number of Persons Producing One Death	
	Males	Females	Males	Females
Greater London	100	100	100	100
County Borough	129	137	125	55
Other Urban Districts	160	156	148	59
Rural Districts	233	185	170	42

Table 25

URBAN-RURAL STUDY OF MALE  
NONSMOKERS\*

Area studied†	No. lung ca. deaths non- smokers	Areas comp.	Rel. diff. lung ca. mort., %
Rural	5	Liverpool: rural	127
Mixed	7	Mixed: rural	-14
Liverpool	18	Liverpool: mixed	163
Lancashire	10	Lancashire: rural	14
		Lancashire: mixed	32

\*Stocks' report\* of a male population 35 to 74 years of age, 1952-1955.

†The rural area studied was North Wales; the mixed area, Denbigh. Liverpool and Lancashire are urban areas.

Table 26

URBAN-RURAL STUDY OF NONSMOKERS\*

Area	Death rate, lung cancer†
Basin area Cincinnati, Ohio	25
Suburban Cincinnati, Ohio	33
Rural Ohio	14

\*Mills' report\* of men 40 years of age and older in a sample population of rural Ohio and Cincinnati, Ohio, 1947-1955.

†The relative difference between lung cancer deaths in the basin area of Cincinnati, Ohio (urban) and rural Ohio was 79%.

Metropolitan counties (8)	122.9
Urban counties (7)	81.8
Rural counties (73)	68.6

The standard mortality ratio is **Ohio**  

$$\frac{\text{Observed deaths}}{\text{Expected deaths}} \times 100$$
 Mancs.

Table 28

Smoking Habits of Men in Different Areas of Denmark in 1952-53\*

Part of Denmark	Percentage of				
	Non-smokers and ex-smokers	Light cigarette smokers	Moderate and heavy cigarette smokers	Pipe smokers	Smokers of cigars and cigarettes
Copenhagen	18.5	23.7	12.7	28.9	16.2
Provincial towns	20.9	18.1	7.2	37.4	16.4
Rural districts	25.8	10.5	24	45.3	15.9

\* Extracted from data given by Hamtoft and Lindhardt (1956).

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the overwhelming reason. In analyzing the various statistical data offered in support of this conclusion, it is surprising to note that there was not a single death from lung cancer among the rural non-smokers used by Hammond and Horn. The time has passed for many years which guarantees clean air to the modern farmer. He comes in contact with the exhaust fumes of his diesel tractors, with mists and dusts from pesticides and herbicides, with oils and greases and gasoline exhaust of his trucks and automobiles. It is equally surprising that Stocks and Campbell found almost an identical relative difference in lung cancer mortality rates of urban-rural type for light cigarette smokers and pipe smokers, considering the fact that the 3,4-benzpyrene content of pipe smoke is greater than that of cigarette smoke (Gardon, Alvord, Rand and Hitchcock) and that Stocks has based many of his calculations on the degree of hazard from the inhalation of cigarette smoke and air pollutants on their relative content of this carcinogen.

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Statistical miscalculations of this type can easily occur whenever important environmental carcinogenic factors are omitted from consideration. Wynder and Wynder, Ferrari and Forti, for instance ascribed the lung cancer rate in Venice which corresponded to that found in other Italian cities to cigarette smoking because air pollution in Venice was pronounced as minimal. Apart from a growing degree of air pollution since World War I by motorised launches, there occurs air pollution from the factories located at the adjacent Main land. While Wynder et al. deny that workers from these factories(glass) are admitted to the hospitals of Venice, Ferrari, Fasan, Forti and Rampinelli noted in another survey that there were more glass workers and painters in the cancer group than in the control group. Glass workers as well as painters have occupational contact with known carcinogens affecting the respiratory system(tar and pitch fumes, solvents, metallic pigments). It is also noteworthy that Breslow et al. have not furnished any data available for many years and considered as "privileged information" concerning an excessive frequency of lung cancer among oil refinery workers.

Conclusions drawn concerning a cigarette smoke etiology of the urban-rural differences in lung cancer rates arrived at without due consideration of the total environmental evidence are therefore of dubious value and may be misleading. An absolute denial that urban air pollution as reflected in differences of urban-rural lung cancer rates has no or little effect upon the degree of urban lung cancer hazards moreover disregards the fact that there is a close chemical similarity in the composition of cigarette smoke and urban air pollutants, since both contain polycyclic aromatic hydrocarbons of known carcinogenic qualities, arsenicals from the combustion of coal, the use of pesticides and the refining of ores, chromates and nickel from the smelting of metal ores and the production and use of metallic carcinogens as well as of their various compounds in industry and as antioxidants in gasoline (nickel), and radioactive materials of natural and man-made origin (Hueper and Conway; Hueper, 1955, 1966; Cooper and Lindsey; Falk and Steiner; Sula; Vondracek; Pybus; Kotin, Falk and Thomas; Falk and Kotin; Kotin, Falk; Mader and Thomas; Commins, Waller and Lawther; Smith; Doll; Katz; Mallet; Sawicki; Fox, Elbert, Hauser and Meeker; Waller; Campbell and Clemmesen; Dikun, Shabad and Norkin; Shabad; Blacklock, Kennaway, Lennaway and Urquhart; Wynder and Hoffmann; Mittler and Nicholson; Epstein, Joshi, Andrea, Mantel, Sawicki, Stanley and Tabor; Hoffmann and Wynder; Hueper, Kotin, Tabor, Payne, Falk, and Sawicki) Annotations (Moore and Katz; Sawicki, Meeker, and Morgan) Lyons).  
Recent observations have shown that urban pollutants may contain also other carcinogens, such as the effluents of asbestos plants and asbestos abrasions (Harington and Smith) from brake linings, nitroolefins (Memill; Lampe and Deichmann; Deichmann; et al.) and carcinogenic oil additives of automobile engine lubricants (Balwin, Cunningham and Pratt) Dooley).

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Table 31

TABLE 13.—3,4-Benzpyrene Content in the Particulate Phase of Air Pollutants of English Cities (R. E. Waller)

City	Median Ann. Concent. of 3,4-Benzpyrene, $\mu\text{g}/100$ Cu M Air	Smog Days
London	4.6	
Sheffield	4.2	17.3
Leicester	2.9	
Burnley	2.7	
Bilston	2.7	
Cannock	1.9	
Hull	1.8	
Bristol	1.3	

Table 32

TABLE 3.—Range of Maximum Metal Levels in Selected Cities (Tabor and Warren)

Metal	City	Low Level, $\mu\text{g}/\text{CuM}$	High Level, $\mu\text{g}/\text{CuM}$	City
Zinc	Fort Worth	0.4	49.00	Chicago
Iron	Lakehurst	0.23	30.00	East Chicago
Copper	Washington	0.05	30.00	Boston C
Lead	Lakehurst	0.33	17.00	Boston
Manganese	Lakehurst & Paulsboro	<0.01	3.00	Chattanooga
Barium	Lakehurst & Paulsboro	<0.005	1.50	Houston
Tin	Tampa	0.004	0.80	Boston
Vanadium	Fort Worth	0.002	0.60	Jersey City
Titanium	New Orleans & Tampa	0.01	0.24	East Chicago
Nickel	Houston C	0.005	0.24	East St. Louis
Chromium	Lakehurst	<0.002	0.12	New York
Cadmium	Boston	0.002	0.10	East Chicago
Bismuth	Boston C	<0.002	0.03	East St. Louis
	Minneapolis			New York

Table 43

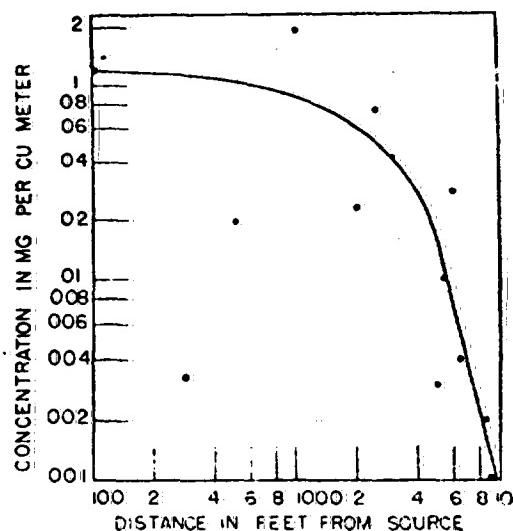


Fig. 3.—Range of general atmospheric pollution with chromium in general environment of a plant in Cleveland (Bourne and Rushin).

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Table 29

Sawicki et al.

## Polycyclic Hydrocarbon Content of the Air for Selected Cities

City	Month	BghiP*	BaP	BeP	BkF	P	Cor	Per	Anth	Total
<b>Winter 1959 (<math>\mu\text{g}/1000 \text{ m}^3</math>)</b>										
Atlanta	Feb.	8.9	7.4	4.7	6.0	6.0	4.3	1.1	0.52	38.92
Birmingham	Feb.	18	25	10	13	17	3.5	5.5	2.2	94.2
Detroit	Feb.	33	31	23	20	25	6.4	6.0	2.0	146.4
Los Angeles	Feb.	18	5.3	8.1	5.7	6.0	12	1.6	0.16	56.86
Nashville	Jan.	17	25	14	15	30	4.6	4.4	1.8	111.8
New Orleans	Feb.	7.3	4.1	6.4	3.9	2.3	27	0.8	0.10	27.6
San Francisco	Jan.	7.5	2.3	2.9	1.7	1.9	4.9	0.34	0.10	21.64
Seattle	Jan.-Mar.	14	9.0	—	8.1	6.7	15	2.4	1.0	56.2
Sioux Falls	Jan.-Mar.	8.3	4.0	—	2.7	4.0	3.7	0.82	0.22	23.74
South Bend	Jan.-Mar.	12	16	14	10	32	4.7	3.0	1.5	93.2
Wheeling	Jan.-Mar.	14	21	—	13	22	3.8	2.6	1.4	77.8
Youngstown	Jan.-Mar.	22	28	—	18	34	3.4	7.4	3.4	116.2
<b>Summer 1958 (<math>\mu\text{g}/1000 \text{ m}^3</math>)</b>										
Atlanta	July	5.1	1.6	1.5	1.3	0.73	2.5	0.40	0.2	13.3
Birmingham	July	8.3	6.4	5.9	4.6	2.1	2.4	2.1	0.25	32.05
Detroit	July	9.5	6.0	5.3	4.9	2.8	1.8	1.7	0.38	32.38
Los Angeles	July	2.3	0.5	0.63	0.45	0.27	2.2	0.034	0.03	6.41
Nashville	July	3.4	1.4	1.2	1.0	0.58	1.3	0.21	0.06	9.15
New Orleans	July	4.6	2.0	3.1	1.8	0.34	2.5	0.39	0.1	14.8
San Francisco	July	2.6	0.25	0.54	0.24	0.09	1.6	0.043	0.022	5.39
Cincinnati	July	6.0	3.9	4.0	3.5	1.7	2.8	0.93	0.07	22.9
Philadelphia	May	6.8	3.4	2.5	2.5	2.2	2.9	0.78	0.12	21.2

Table 30

**Benzo(a)pyrene concentration varies from city to city around the United States. Here's the scoreboard on this carcinogen for nine U. S. cities in November 1958:**

City	Approximate Location	BaP Concentration in...	
		Particulate ( $\mu\text{ gm./gm.}$ )	Air ( $\mu\text{ gm./1000 m}^3$ )
E	west	5.1	1.9
I	west	30.0	3.2
G	south	32.0	2.9
H	east	39.0	7.0
A	southeast	54.0	7.6
D	north central	70.0	10.3
C	north central	98.0	14.4
F	south	102.0	19.6
B	south	106.0	29.9

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B. Atmospheric Pollution<sup>ion</sup> versus Cigarette Smoke

The increasing pollution of the air of the general environment, the occupational atmosphere, and the home is indicated by the two graphs showing the rise of the annual production of cancer-related industrial chemicals between 1900 and 1948 in the United States and the trends of selected environmental factors in the United States during 1900 and 1953 which may have and have produced a contamination of the air (Hueper, 1955; Hammond, 1960). Chemical data demonstrate that many urban populations have inhaled for many years larger amounts of carcinogens with the general air than medium to heavy cigarette smokers and have more <sup>out</sup> introduced into their bodies carcinogenic chemicals which have shown in members of special occupational groups a much higher carcinogenic potency than that displayed in heavy smokers by cigarette smoke. Urban populations are exposed to atmospheric pollution not only from infancy but also twenty-four hours a day without interruption for many years.

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An expert panel of the State of Pennsylvania ventured in 1963 the opinion that only 8,000 lung cancer deaths out of a total of 36,000 in the United States could be ascribed to the action of air pollutants, the rest were caused by cigarette smoking. Stocks and Campbell, on the other hand, concluded from their study of the Liverpool area that about 50 per cent of the lung cancer deaths in Liverpool men were due to cigarette smoking and that about 75 per cent of the remaining half were due to a factor only slightly present in rural areas. Prindle agreed with <sup>w</sup>Hammond that urbanization factors contributed about 20 per cent to the total lung cancer death rate. Cooper, Lindsey and Waller concluded from their studies of the benzpyrene content of air pollutants and cigarette smoke that an individual smoking 40 cigarettes daily would inhale per year 150 mgms of 3,4-benzpyrene, while during the same period he would inhale from the atmosphere about 200 mgms. of this chemical. The Medical Research Council had this to say about the problem in 1957: The daily intake of benzpyrene from breathing the air in a west country town was equivalent in total volume to the intake from smoking about 40 cigarettes a day; that from breathing London air

was equivalent in total volume to the intake from smoking about 100 cigarettes a day. Pybus commented in 1959 that the total production per year of 180 million tons of coal burnt in Great Britain produced 2,500,000 tons of smoke containing about 750 tons of benzpyrene, while 111,607 tons of tobacco smoked yielded 18,000 tons of smoke containing 8 lb. of this chemical. Pybus maintained that on the basis of this calculation 90 per cent of all lung cancers in Britain are caused by carcinogenic air pollutants. According to Pybus, the air of London and many other places which the inhabitants breathe every day contains, on average, an amount of benzpyrene equal to smoking 100 cigarettes. Griffith basing his calculations on the chemical data provided by Sawicki et al. on the benzpyrene content of the air of London advanced a more conservative estimate, when he noted that non-smokers in London inhale much more benzpyrene than the moderate smoker in a rural environment. Strach had this to say on this subject: Tobacco consumption does not suggest any causal link to lung cancer; from 1925 to 1960 the same number of cigarettes were smoked per person in Germany and in the Netherlands but 2.5 times as many <sup>in 1960</sup> in the U.S.A.; The cancer of the lung mortality rate per 100,000 population was in the United States in 1952 at 21 and in 1962 at 31, it was in West Germany at 21 and 33, respectively, and in the Netherlands at 25 and 41, respectively. Non-smokers in an air polluted town inhaled during their life time 14 times as much 3,4-benzpyrene as a cigarette smoker produces during ~~the consumption of 100 cigarettes~~ <sup>in five minutes</sup>. An idling motor car can produce just as much 3,4-benzpyrene as a cigarette smoker produces in 22 years (Germany); the annual carcinogenic automobile exhaust gases come to something like several hundred tons and are chiefly generated in residential districts. cigarette consumption in Germany yields yearly in contrast 1.4 kg. of 3,4-benzpyrene; cigarette consumption is not dependent on the housing density.

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These data evidently militate strongly against the categorical allegation that cigarette smoking represents the predominant cause of lung cancer and that therefore radical control measures against this habit would

provide an effective and far reaching control of the rising tide of lung cancer deaths.

### C. Socioeconomic and Occupational Factors

During the last three decades a large amount of circumstantial as well as conclusive evidence has accumulated indicating the operation of numerous exogenous agents many of which are occupational, specific and well identified in the causation of lung cancers and in the appearance of marked variations in the frequency and distribution of these tumors upon well circumscribed population groups. The various occupational carcinogens of identified and nonidentified types are responsible for the observed differences in lung cancer rates among members of the various socioeconomic groups which are formed according to occupational, economic and residential criteria. They account also for such fluctuations among different professional and trade groups as well as among groups of individuals who have special occupational contact with these agents. Although protagonists of the cigarette theory often find it advantageous to maintain that the action of occupational factors in pulmonary carcinogenesis is limited to rather small population groups and thus of minor importance in the general problem of lung cancer hazards and increased frequency of these cancers, a competent appraisal of this facet must assign to them a considerably more important role, apart from the fact that they are also the only environmental pulmonary carcinogens of established identity and therefore amenable to relatively well controlled epidemiologic analysis and preventive control.

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### 1. Socioeconomic ~~Assortations~~

The different groupings of populations on the basis of socio-economic criteria have used various principles: Registrar General's Office constructed five classes according to types of occupation; Buell, Dunn and Breslow divided the population into five classes according to income; Cohart grouped the population of New Haven, Connecticut into 3 classes on the basis of home rent and income; and Mancuso used census tracts in the Cleveland, Ohio, area for this purpose. It is obvious that each of such classes reflecting socioeconomic gradients includes often not only a variety of occupations having a variety of occupational exposures, but comprises also a consideration of living conditions, residence, traffic conditions, habits, medical care, and social activities. Because of this rather mixed character socio-economic classes can be expected to reveal only rather distinct differences in the liability of their members to develop cancers of various sites, such as the lung, which moreover may be due to a variety of occupational or environmental carcinogens.

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Despite these methodologic limitations several comprehensive epidemiologic surveys based on socioeconomic classes have disclosed the fact that there is a progressive rise in the lung cancer frequency paralleling a drop in the socioeconomic level (Registrar General; Stocks; Mancuso and Courter; Brockbank; Herdan; Clemmesen and Nielsen; Graham, Levin and Lilienthal; Kennaway), thereby revealing a distinct social class gradient. There is no sound and rational reason to assume that differences in cigarette smoking are the underlying cause of this although Buell, Dunn, and Breslow have given figures purportedly showing this relation phenomenon. Gilmore and Anderson commenting on such observations noted that occupational exposure to carcinogens and socioeconomic conditions are variables which may be factors determining lung cancer rates in urban populations. It should be mentioned that neither Hagstrom, Sprague and Edgehill in their study of the lung cancer incidence of the population of the highly polluted Nashville nor Pernue reporting on the epidemiology of lung cancer in Finland could demonstrate any socioeconomic gradient in the distribution of lung cancers.

## 2. Trades and Professions

Some representatives of industry as well as protagonists of the cigarette theory of lung cancer favor the view that occupational ~~cancers~~ <sup>gens</sup> are the least important factors in pulmonary carcinogenesis (Levin, Kraus, Goldberg, and Gerhardt; Clemmesen, Wynder and Mantel, <sup>Eckhardt;</sup> Pell and Fleming). Faulty methodology of investigation seems to be a frequent reason for this erroneous conclusion, which is moreover aggravated by the claim that only a relatively small number of workers become exposed to such agents. In the recent communication of Pell and Fleming no attempt has been made to distinguish between long term and short term employees, between workers engaged in the various and specific chemical operations some of which doubtlessly entail contact with known carcinogens active on the respiratory organs. In Wynder and Mantel's survey of lung cancer among Jewish males it is contended that data on place of residence and occupation do not account for the reduced lung cancer rate among Jewish males compared with non-Jewish males. While Seidman confirms the general information on the low lung cancer rate among Jewish males, he cautiously adds that the proportion of Jewish males occupational<sup>ly</sup> exposed to inhalants, such as gas, dust and fumes, was smallest when compared with that of Catholic and Protestant males. The original conclusion reached by Kraus of the statistical significance of the occupational data obtained in the publication of Levin, Kraus, Goldberg and Gerhardt, just referred to, read as follows: "It is hard to believe that each of the significant results is really due to an association with smoking; rather than direct occupational factors". The occupational groups with high and significant lung cancer rates were construction workers, makers of metal products and printers. The published version, on the other hand, placed the blame for such observations on cigarette smoking.

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Breslow commented in 1955 quite appropriately that "the "justified concern about cigarette smoking as a cause of lung cancer too little note has been taken of evidence that several occupations may likewise play a causal role."

As to the relatively small number of workers exposed to known or suspected respiratory carcinogens a partial list of the type and number of such workers in the United States in 1950 may serve as an illustration: Technical engineers, 535,000; garage managers, 24,000; managers of gasoline service stations, 148,000; blacksmiths, 45,000; cranemen, 106,000; locomotive engineers, 73,000; locomotive firemen, 56,000; forgemen, 14,000; machinists, 533,000; foremen in metal industries, 516,000; automobile mechanics, 677,000; railroad mechanics, 48,000; metal molders, 64,000; construction painters, 431,000; photoengravers, 29,000; printers, 50,000; stationary engineers, 218,000; apprentices to automobile mechanics, 120,000; asbestos workers, 16,000; conductors of buses and railroad, 11,000; bus drivers, 157,000; metal grinders and polishers, 155,000; furnace men and smelter workers, 57,000; metal heaters, 10,000; oilers, 61,000; painters, 122,000; textile spinners, 85,000; stationary firemen, 128,000; taxicab drivers, 212,000; truck drivers, 1,396,000; welders, 275,000; metal industry workers, 545,000; printing workers, 78,000; petroleum and coal products workers 53,000; rubber products workers 123,000; metal industry laborers 281,000; etc. This partial list of variously exposed individuals may suffice to give a more adequate information concerning the scope of the working population exposed to occupational carcinogens of some kind.

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A considerable number of epidemiologic surveys dealing with the frequency of lung cancer among members of large but specific worker groups or with lung cancer mortality rates among members of specific trades, occupations and professions have produced impressive circumstantial evidence supporting the view that occupation-related factors must account for the marked differences in cancer rates found among such population groups.

1937-39 MORTALITY EXPERIENCE AMONG WHITE MALE WAGE EARNERS  
INSURED UNDER INDUSTRIAL POLICIES IN METROPOLITAN LIFE INSURANCE COMPANY

Lew  
Table 31

Occupations with Probably Higher Than Average Death Rate from Cancer of the Lungs

<u>Occupation</u>	<u>Number of Deaths From All Causes</u>	<u>Number of Deaths from All Forms of Cancer</u>	<u>Number of Deaths from Cancer of Lungs</u>	<u>% Deaths from Cancer of Lungs to Deaths from All Causes</u>	<u>% Deaths from Cancer of Lungs to Deaths from All Forms of Cancer</u>
All wage earners	112,991	13,858	1,682	1.5	12.1
Blacksmiths	503	75	11	2.2	14.7
Brick and stone masons*	722	124	18	2.5	14.5
Cooks - hotel and restaurant+	345	48	8	2.3	16.7
Coppersmiths, tinsmiths, etc.+					
- not roofers	402	61	9	2.2	14.8
Engravers (metal) and photoengravers	84	15	5	6.0 ←	33.3 ←
Laundry workers (exc. laborers)	222	27	5	2.3	18.5
Mail Carriers	242	41	7	2.9	17.1
Miners (underground, excluding coal miners)	222	20	6	2.7	30.0 ←
Painters and varnishers - house, shop, etc.	2,821	366	62	2.2	16.9
Plasterers	190	31	5	2.6	16.1
Plumbers, steamfitters and gasfitters+	1,178	156	29	2.5	18.6
Roofers and slaters+	225	31	5	2.2	16.1
Slaughter and packing house operatives	279	41	7	2.5	17.1
Street cleaners	336	64	9	2.7	14.1
Tannery operatives	227	33	5	2.2	15.2
Tailors and other clothing workers	1,564	228	37	2.4	16.2
Traveling salesmen	374	46	10	2.7	21.7
Welders*	216	24	7	3.2	29.2 ←

\*In these occupations the mortality from all forms of cancer was somewhat higher than average as follows:

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brick and stone masons	155% of average
Cooks - hotel and restaurant	119% of average
Coppersmiths, tinsmiths, etc. - not roofers	123% of average
Plumbers, steamfitters and gasfitters	110% of average
Roofers and slaters	112% of average
Welders	126% of average

Table 32

The Resulting Observed Over Expected Ratio  
 of Lung Cancers in Occupational  
 Groups in California  
 (Dunn, Linden and Breslow)

Occupational Group	Lung Cancers Observed	Lung Cancers Expected	Ratio Observed over Expected
Welders	22	19.3	1.14
Painters	44	27.7	1.48
Cooks	27	16.3	1.66
Asbestos Workers	22	15.6	1.41
Printers	2	8.1	0.25
Electric bridge, crane operators		0.54	
Plumbers	19	15.0	1.27
Sheet metal Workers	4	6.3	0.63
Controls	20	19.8	1.01

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Table 33

27

Excessive Lung Cancer Rates in Members of Various  
Occupational Groups

Occupations	Author and Year
Waiters, truck drivers, police men, road construction workers, metallurgical workers	Wachsmuth and Viereck 1964
Furnace men and Painters	Fulton, 1949
Workers in dusty jobs	Kreyberg, 1955
Workers in outdoor jobs, factories and commercial establishments	Mittmann, Kneller and Poche, 1962
Engineers, mechanists, cutlers, steel foundry workers, furnace men, grinder, polishers, nonferrous metal workers	Turner and Grace, 1938
Asbestos workers, printers	Dunn and Weir, 1965
Engravers, painters, welders, copper smiths	Dublin and Vane, 1939
Outdoor workers (road dust)	Kennaway and Kennaway, 1947
Welder, sheet metal workers, steam fitters, boiler makers, asbestos workers, crane operators in metal industry, smelter workers of non-ferrous ores, marine engineers, commercial cooks	Breslow, Hoaglin, Rasmussen and Thomas, 1954
Metal industry workers, wood workers	Berndt, 1963
Cellarmen, victuallers, tobacco manufacturers, tobacconists, tar workers (gas stokers, gas works employees, gas fitters, chimney sweeps, gas work laborers, patent fuel workers	Kennaway, 1936
Grain dockers	Dunner and Hicks, 1953

20150317-2

Table 33 continued

21

-2-

Excessive Lung Cancer Rates in Members of Various  
Occupational Groups

<u>Occupations</u>	<u>Author and Year</u>
Boiler scalers	McLaughlin, 1944
Painters, oilers, gasoline and garage workers, truckers, metal grinders and polishers, arsenic workers, carpenters, workers em- ployed in hot metal fume work	Wynder, 1954
Worker in dusty operations	Schmidt-Uebereiter, 1959
Platers, riveters, shipwrights, electrical apparatus workers, fitters, electricians, molders, masons, stone cutters, foundry workers, dock laborers, crane drivers, Painters	Morrison, 1957
Waiters, chemical plant workers, railroad employees, Spohn, Damm and Baz, 1960 drivers	
Employers, clerks, metallurgical workers, trans- portation workers, drivers,	Agnese et al., 1959
Technicians, blacksmiths, steel workers, communi- cation workers	Chiurco and Tarrentini, 1959
Engineers, mechanics, painters, welders, crane welders, derrick men, tool dresser, oil drillers crane men	Editor, Brit. Med. J. 1944 Breslow, 1953
Mechanics, engineers, painters	Harnett, 1952
Machine operators, factory workers, technicians	L'Ellore, 1964
Transportation and railroad workers	Krasne et al. 1963
Building construction workers, metallurgical worker, clerks, professionals	Lombardo, 1961
Transportation workers, iron and metal workers, construction workers, hotel and barmen, in- dustrial workers	Kretz, 1953

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Table 33 continued

-3-

29

Excessive Lung Cancer Rates in Members of Various  
Occupational Groups

<u>Occupations</u>	<u>Author and Year</u>
Drapers, barbers, butchers, university men, masters, office workers, diamond cutters, commercial travellers, hall porters, cigar makers, tobacconists,	Versluys, 1949
Managers, metal-and machine workers, transportation workers, painters, foundry workers, lathe workers, welders, blacksmiths, copper and brass workers, chauffeurs	Agnese et al., 1959
Outdoor workers; industrial workers, transportation workers (drivers, railroad employees, messengers, policemen, etc.)	Poche, Mittmann and Kneller, 1964
Craftsmen, service workers, laborers (not on farm or in mine)	Buell, Dunn, and Bres- low, 1960

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37

Table 24  
 Dubin et al.

TABLE 24.—Mortality Experience Among White Male Wage Earners Insured Under Industrial Policies in the Metropolitan Life Insurance Company 1937-1939: Occupations with Probably Higher-Than-Average Death Rates from Cancer of the Lungs

Occupational Group	Deaths from All Causes	Deaths from All Forms of Cancer	Number	Deaths from Cancer of Lungs	
				Percentage Relative to Deaths from All Causes	Percentage Relative to Deaths from All Forms of Cancer
All wage earners.....	112,901	13,638	1,682	1.6	12.1
Blacksmiths .....	503	75	11	2.2	14.7
Brick and stone masons*.....	722	124	18	2.5	14.5
Cooks—hotel and restaurant*.....	345	48	8	2.8	16.7
Coppersmiths, tinsmiths, etc.*—not roofers.....	402	61	9	2.2	14.8
Engravers (metal) and photoengravers.....	84	15	5	6.0	33.3
Laundry workers (except laborers).....	222	27	5	2.3	18.6
Mail carriers .....	242	41	7	2.9	17.1
Miners (underground, excluding coal miners).....	222	20	6	2.7	30.0
Painters and varnishers—house, shop, etc.....	2,621	366	62	2.2	16.9
Plasterers .....	190	31	5	2.6	16.1
Plumbers, steamfitters, and gasfitters*.....	1,178	156	29	2.5	18.6
Roofers and slaters*.....	225	31	5	2.2	16.1
Slaughter and packing-house operatives.....	279	41	7	2.5	17.1
Street cleaners .....	336	64	9	2.7	14.1
Tannery operatives .....	227	33	5	2.2	15.2
Tailors and other clothing workers.....	1,564	228	37	2.4	16.2
Traveling salesmen .....	374	46	10	2.7	21.7
Welders* .....	216	24	7	3.2	29.2

\* In these occupations the mortality from all forms of cancer was somewhat higher than average as follows:

Brick and stone masons.....	155% of average
Cooks—hotel and restaurant.....	119% of average
Coppersmiths, tinsmiths, etc.—not roofers.....	123% of average
Plumbers, steam fitters, and gas fitters.....	110% of average
Roofers and slaters.....	112% of average
Welders .....	128% of average

Table 25

Table 25. Lung cancer death rates per 1,000 deaths from all causes for 7 industrial groups in Ohio, 5,309 males, 1947 (Mancuso)

Industry	Death rate
Nonferrous metal.....	3.22
Transportation.....	2.91
Rubber and plastics.....	2.34
Iron and steel.....	2.18
Mining and quarrying.....	1.53
Agriculture.....	.82
Stone, clay, glass.....	.66
Total.....	1.76

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Table 36

TABLE XII. MORTALITY FROM LUNG CANCER AND ALL CAUSES. SPECIFIC OCCUPATIONS WITH SIGNIFICANTLY DIVERGENT S.M.R.S FOR LUNG CANCER IN CALIFORNIA MEN, AGES 20 TO 64, 1949 TO 1951

SOCIAL CLASS	OCCUPATION	LUNG CANCER DEATHS			ALL CAUSES S.M.R.
		OBSERVED	EXPECTED	S.M.R.	
<i>Lung Cancer S.M.R. Above 100</i>					
I	Authors, etc.	11	6.3	175	107
III	Bookkeepers	12	6.4	188	100
III	Carpenters	108	74.7	145	89
III	Machinists, etc.	44	32.1	137	122
III	Plumbers, pipefitters	27	18.5	146	110
III	Stationary engineers	29	15.4	188	145
IV	Mine workers	29	11.6	250	225
V	Sailors, deck hands	11	3.8	289	272
IV	Taxicab drivers	16	7.4	216	139
IV	Cooks (not private)	44	24.4	180	184
V	Fishermen	11	5.6	196	106
V	Laborers (not farm or mine)	155	118.7	131	162
<i>Lung Cancer S.M.R. Below 100</i>					
I	College faculties	1	4.8	21	30
I	Civil engineers	4	10.9	37	89
I	Electrical engineers	1	5.8	17	72
II	Teachers (n.e.c.)*	4	12.5	32	64
II	Managers, trade	92	140.5	65	82
III	Other clerical workers	80	98.7	81	82
V	Janitors	33	47.1	70	78
V	Other specified laborers (mainly gardeners)	16	31.5	51	64

\*N.e.c., not elsewhere classified.

Table 37

TABLE 28.—Standard Mortality Rates of Malignant Neoplasms of the Respiratory System in Occupational Classes in Scotland (Morrison)

Occupational Code No.	Occupation	SMR:
Above 130		
160-164	Platers, riveters, shipwrights	163
231-249	Electrical apparatus makers, electricians	170
131,132	Moulders	162
589	Masons and stone cutters	162
134-138	Foundry workers, etc.	161
681	Dock laborers	157
912	Crane drivers	150
600-609	Painters, decorators	132
Below 70		
019, 021, 029	Farm workers	25
010, 011, 018, 020	Farmers, etc.	27
110-119	Foremen & overlookers in metal manufacture	34
013-015	Market or other gardeners	56
630-629	Managers or industrial undertakings other than managers of office departments	69

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Observations on this subject have been reported over a number of years from several industrialized countries (England and Wales; Netherlands; U.S.A.; Scotland; Germany; Austria) (Stocks; Lew; Mancuso; Kennaway and Kennaway; Morrison; Registrar General; Breslow; Herbich and Neuhold; Bobke, Mittmann, and Kneller). Numerous additional communications list an excessive liability to lung cancer for various professions and trades (Tsuchiya; Lombardo; Agnese, De Veris and Santolini; Kretz; Wynder and Graham; Versluys; Clemmesen; Schmidt-Ueberreiter; Stocks; Buell, Dunn and Breslow; Krassne and Synkova; L'Eltore; Fulton; Ravara; Turner and Grace; Harnett; Chiurco and Tarantini; Agnese, De Vern, and Santonini; Berndt; Spohn, Daum, and Benz; Wynder; McLaughlin; Harding and McLaughlin; Dunner and Hicks; Breslow, Hoaglin, Rasmussen and Abrams; Dublin and Vane; Kreyber; Wachsmuth and Viereck; Hueper). Table 31-37

It is significant that many of the occupational groups mentioned as having an excessive liability to acquire lung cancer are part of the previously given list of numbers of individuals employed in different trades consisting of many millions of gainfully employed American citizens. The total number of persons exposed to occupational pulmonary carcinogens therefore cannot be considered as of minor importance. It merely has not been adequately surveyed for evidence of occupational lung cancers and of their specific causative agents, although industrial managements, governmental public health agencies and labor unions have been aware of such cancer hazards for many years. An overriding desire motivated in part by selfish reasons among these parties to maintain cordial relations and to protect the social and economic equilibrium can scarcely be regarded as an acceptable excuse for such a policy which represents moreover an effective sabotage of enlightened preventive cancer control programs especially as far as public health agencies are concerned.

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